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Richard E. Looker, Water Resources Control Engineer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

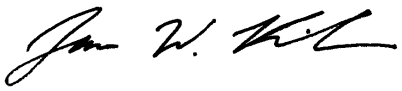
Dear Mr. Looker,

I have reviewed at length the proposed basin plan amendment and staff report, dated 24 October 2003, for the mercury TMDL for San Francisco Bay. My review is attached.

My review addresses the draft report alone, and not the references cited therein; for the purposes of this review I have assumed that those cited references do in fact substantiate the points for which they are cited.

Please let me know if you would like any clarification of the points raised in the attached review, or if there is any other way that I can be of assistance.

Sincerely,



James W. Kirchner
Professor

Review of technical basis of proposed basin plan amendment for mercury TMDL for San Francisco Bay

James W. Kirchner
Professor of Earth and Planetary Science
University of California, Berkeley

1. The problem statement

a) Has the nature of the water quality problem of mercury in San Francisco Bay been described reasonably?

The problem description is reasonable. The 'key points' present a very concise summary. One minor comment concerns Figure 2.2. The caption says that concentrations have been measured annually from 1993 through 2000, but the figure clearly shows more frequent sampling than that. One also assumes that there have been measurements since 2000; if so, why aren't these shown?

2. Mass budget approach

a) Does the draft clearly describe the steady-state box model employed in the analysis?

It would help to more clearly describe the overall model as early as possible in the analysis. Conceptually there are two box models, a steady-state box model for sediment, and a non-steady-state box model for mercury. The box model for mercury is largely derived by weighting each term in the sediment model by the relevant sediment mercury concentrations.

It is important to emphasize that the steady-state assumption for sediment pertains to the water column in the Bay. Thus it makes sense that net inputs to the water column (bed erosion and inputs from runoff, etc.) should equal net exports from the Golden Gate. This is different from assuming that the net inputs and outputs to the Bay plus its sediments are in balance (which would be equivalent to assuming that there was no net bed erosion or deposition).

Minor comment: a sentence on page 12, "When a system is at steady state, missing information about inputs and outputs can often be derived from available information about inputs and outputs," should be clarified. Something more needs to be said here. In practice all that the steady-state assumption means is that the net sum of unmeasured inputs and outputs must equal the (negative of the) net sum of measured inputs and outputs. This is useful, but one can only take it so far.

b) Does the draft reasonably support the rationale for employing a steady-state box model for the purpose of the TMDL analysis?

Yes. The box model is a reasonable approach for analyzing the situation at hand, without over-interpreting the limited data that are available.

3. Source assessment

a) Are the source categories clearly defined?

Yes, generally. One possible source of confusion is the handling of stormwater load vs. mining legacy load for the Guadalupe River. This could be confusing because the mercury from the mines will

predominantly be discharged from the Guadalupe River in association with storm flows, but this is not what is meant by "stormwater load". One should make clear that what is termed "stormwater load" is the stormwater contributions from the surrounding watershed except for the effects of the mines.

b) Are the source estimates and estimation methodologies clearly stated for each source category?

Yes, generally. One possible source of confusion is found on page 29: "Some fraction of each sediment source is assumed to exit through the Golden Gate." This implies that these fractions are known or assumed, whereas they are not stated in the document, and in fact they are unnecessary. The box model does not require that the fate of sediment from each source is separately knowable. (Note that on page 30, a verb is needed in the sentence that begins, "Table 4.7...").

c) In view of the data available, are the estimation methods employed reasonable and scientifically sound?

Yes. It is important to recognize that the uncertainties are large in some cases; for example, because sediment fluxes through the Golden Gate are uncertain within about a factor of two, mercury fluxes through the Golden Gate are uncertain by roughly the same multiple. This makes the mass balance for the Bay highly uncertain -- ranging from about a net gain of 50 kg Hg/yr to a net loss of 1130 kg Hg/yr.

4. Numeric targets

a) Are the target derivations clearly stated and adequately supported by available information?

The fish tissue target assessment may be misstated or incorrectly done. On page 34, it says that to lower the mercury concentration to 0.2 ppm, concentrations would need to be reduced by about 40%. But figure 5.1 shows the median concentration, not the mean, which is what controls the average exposure to consumers. If the mean concentration in striped bass is greater than 0.33 ppm (which it appears to be from figure 5.1), then the concentrations would need to be reduced by more than 40% to achieve the average exposure that is intended by the 0.2 ppm standard.

The rationale behind the wildlife target is problematic. Significant adverse effects have been found for egg concentrations above 0.5 ppm, but the concentration at which no toxic effects occur is simply unknown. USEPA has suggested a no-adverse effects level of 0.25 or 0.17 ppm (1/2 to 1/3 of 0.5 ppm). As the document indicates, more research is needed here. But one cannot assume, as stated on page 37, that "If bird egg concentrations drop below 0.5 ppm, detrimental effects are unlikely to occur." Page 35 states that the no-adverse-effect level is somewhere below 0.5 ppm (possibly 1/2 or 1/3 of that value); one cannot assume two pages later that the no-adverse-effect level is exactly at 0.5 ppm.

5. Linkage analysis

a) Are the linkages between sources and the numeric targets clearly stated and scientifically sound?

On page 43, one finds the statement, "Mercury methylation rates in surface sediment directly relate to mercury concentrations in the sediment..." It is unclear what "relate to" means. Does this mean that methylation rates are proportional to sediment concentrations? If so, say so. Does it mean instead that methylation rates are a linear (or maybe nonlinear) function of sediment concentrations? Does it mean that methylation rates are correlated with sediment concentrations? More semantic precision is needed.

b) Have we presented a plausible argument that reducing sources of mercury will result in attainment of proposed targets?

Yes, as long as all other factors controlling methylation rates do not change. If, for example, redox conditions in the bay sediments were to shift in a way that favors more rapid methylation, mercury levels in the food chain could increase even though mercury loading to the Bay was decreasing.

c) There are several key assumptions put forth in this section to complete the linkage between mercury loads and fish tissue mercury concentrations. In light of available data, are these assumptions reasonable?

On page 44, it is stated that SFEI's model for mercury in striped bass assumes that "the rate of mercury elimination is linearly related to fish concentrations." This assumption should be examined. It would appear to imply that mercury concentrations should reach an equilibrium within a fish, rather than increasing as the fish ages, which was my understanding of what actually happens. This is not an area in which I have expertise; I am just flagging it as a possible point of concern.

6. Load allocations

a) Are the load allocations and calculation methodologies clearly stated for each source category?

Yes.

b) Are the calculation methodologies for arriving at categorical load allocations reasonable?

Yes, generally. It is somewhat perplexing that the load allocations are derived by assuming a target mercury concentration of 0.2 ppm in sediment, but the allocations themselves are in terms of load rather than concentration. The reason for this should be explained.

c) When load allocations are further distributed among contributing entities (e.g., wastewater and urban stormwater), is the methodology for distributing the load allocation clearly stated and reasonable?

Yes.

d) Given the scarcity of information concerning relative bioavailability and the degree to which mercury from different sources undergoes methylation, is it reasonable to assume that all mercury sources are equally bioavailable?

In the absence of specific information on relative bioavailability, this is the most reasonable approach. However, efforts should be undertaken to assess the relative bioavailability of mercury from different sources, because it could significantly alter the effectiveness of load reduction efforts.

e) There is a discussion in this section regarding the response time of sediment concentrations that makes use of a box model to generate an estimated response time on the order of 100 years. Based on the available information, is the a reasonable conclusion about physical constraints on the expected response time of mercury concentrations in sediments?

This approach is reasonable given the existing information constraints. However, the results depend critically on assumptions that are uncertain (chief among them being the assumption that all mercury, regardless of source and regardless of chemical form, is equally likely to undergo methylation).

7. Margin of safety

a) Does the draft adequately identify the limitations of the technical information that is currently available?

Yes.

b) Is the method of ensuring an implicit margin of safety clearly stated and reasonable?

The adaptive implementation strategy is critical for providing a margin of safety. The conservatism in the targets and allocations is appropriate, but one cannot say that it will "ensure, in the face of uncertainties, that the targets and water quality standards will be met" (page 57). Key uncertainties, such as the factors regulating methylation rates, are potentially larger than the implicit margin of safety provided by the conservatism in targets.

The last paragraph of page 58 provides a case in point. The fact that the modeled sediment mercury concentration is 0.15 ppm, which is less than the target of 0.2 ppm, does not demonstrate that the "analysis is sufficiently conservative". It is likely that values well above 0.2 ppm would be within plausible uncertainty bounds for the modeled sediment mercury concentration, if a quantitative uncertainty analysis were performed.

8. Implementation actions

a) Are the actions described in this section reasonable in light of available data?

The implementation plan is reasonable. It is appropriately broad in scope, although necessarily imprecise on some points owing to limitations in the available data.

The implementation plan appropriately recognizes that proposed reductions in mercury loading from the Guadalupe River Watershed are ambitious, and will take years to accomplish. The interim milestone (47 kg/yr, roughly a factor-of-two reduction from current loads) is likely to be relatively easy to achieve, but one would expect that meeting the final target (1.7 kg/yr, a factor of 28 smaller than the interim milestone) will be considerably more difficult.

b) Is the adaptive approach to implementation adequately explained and reasonable?

The adaptive implementation plan is essential for providing an adequate margin of safety. As explained above, the current uncertainties in mercury sources and internal Bay processes (such as methylation processes or natural sediment erosion and deposition) make it impossible to be certain that an adequate margin of safety would be provided by any implementation plan that might be proposed at present. Thus an ongoing program of monitoring, review, and scientific study is needed to ensure that the goals of the TMDL program are being met.

c) Is the proposed monitoring program adequate to evaluate progress toward achieving the sediment, fish tissue, and bird egg targets?

In general, yes. One possible concern is that if the implementation plan is reviewed on a five-year cycle, and fish tissue and bird eggs are sampled only every three years, then in some five-year intervals, fish tissue and bird eggs will only be sampled once. Unless there is little year-to-year variability in fish tissue and bird egg concentrations, this could represent a significant source of uncertainty in the implementation review process.

d) Does the draft clearly state the key management questions?

The key management questions are both clearly stated and adequately explained. The document correctly recognizes that, although it is important to work toward addressing these management questions, making appropriate management decisions does not require a complete understanding of all aspects of mercury in San Francisco Bay.

As a possible addition to the list of management questions, the fate of the estimated 400 kg/yr of mercury in refinery crude oil (mentioned on page 71) is worth considering.

e) Does the draft contain a reasonable approach and schedule for addressing each of the management questions?

In general, yes. It may be appropriate to use controlled experiments, in addition to the observational program outlined on page 80, to try to determine the factors controlling mercury methylation. The question of mercury storage in Bay-Delta tributaries (page 83) is potentially important, but the document should specify what efforts will be undertaken to locate and quantify these channel and bank deposits.

9. Overarching questions

a) Are data used in the report reliable and appropriate, and is the treatment of the data defensible?

To my knowledge, the data used in the report are the best currently available. There are several important information gaps which are clearly identified in the report. The treatment of the data is appropriate; the report neither over-interprets the available data, nor overlooks important data bearing on the matters of interest.

b) Does the report as a whole support its scientific conclusions and recommendations?

Yes.

c) Does the analysis present a sufficiently compelling scientific justification to proceed with the TMDL adoption and implementation plan as proposed?

Yes. The report recognizes that there are key information gaps, but these do not justify indefinite delay in implementing a plan of action. Enough is known about the sources, fate, and effects of mercury in San Francisco Bay to justify the proposed TMDL allocations and the proposed implementation plan. The implementation plan proposed in the report is a reasonable approach to managing mercury in San Francisco Bay, while simultaneously working to fill the critical information gaps, and allows for changes to be made as new information becomes available.